

# Energy Flow in Ecosystems

Organisms need energy to survive, grow, and reproduce. Different organisms get energy from different sources, but the ultimate source of energy for almost all organisms on Earth is the sun.

## Life Depends on the Sun

Energy from the sun enters an ecosystem when organisms use sunlight to make sugar in a process called **photosynthesis**. During photosynthesis, plants, algae, and some bacteria capture light energy from the sun and use it to convert carbon dioxide and water into sugar and oxygen, as shown in **Figure 1.1**. The result of photosynthesis is the production of sugar molecules known as *carbohydrates*. Carbohydrates are energy-rich molecules that organisms use to move, grow, and reproduce. As organisms consume other plants or animals, energy is transferred from one organism to another.

Plants, such as sunflowers, produce carbohydrates in their leaves. When an animal eats a plant, or the fruit or seeds of a plant, some energy is transferred from the plant to the animal. When animals are consumed by other organisms, energy is again transferred.

**FIGURE 1.1**

**Photosynthesis** During photosynthesis, plants use light energy from the sun to make carbohydrates. The chloroplasts in the leaves and stems of these sunflowers contain a green chemical called *chlorophyll*. Chlorophyll absorbs the light energy needed for photosynthesis.



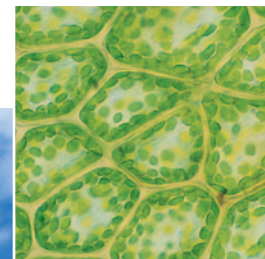
## SECTION 1

### Objectives

- Describe how energy is transferred from the sun to producers and then to consumers.
- Describe one way in which consumers depend on producers.
- Identify two types of consumers.
- Explain how energy transfer in a food web is more complex than energy transfer in a food chain.
- Explain why an energy pyramid is a representation of trophic levels.

### Key Terms

photosynthesis  
producer  
consumer  
decomposer  
cellular respiration  
food chain  
food web  
trophic level



**FIGURE 1.2**

**Transfer of Energy** Almost all organisms depend on the sun for energy. Plants like the clover shown above get energy from the sun. Animals such as the rabbit and coyote get their energy by eating other organisms.



### CHECK FOR UNDERSTANDING

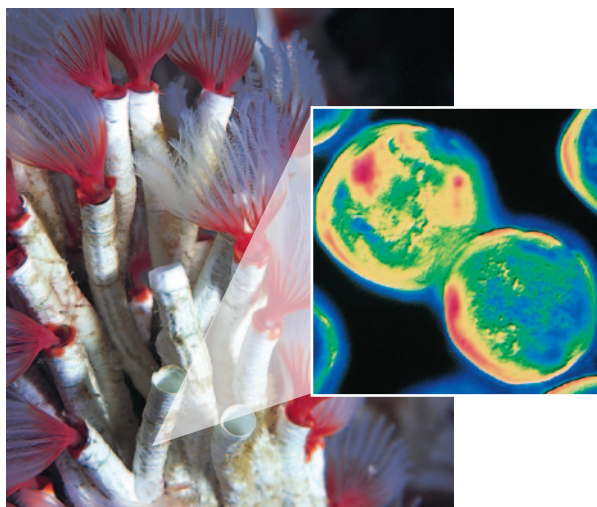
**Relate** How do producers and consumers get energy from the sun?

### From Producers to Consumers

When a rabbit eats a clover plant, the rabbit gets energy from the carbohydrates produced in the plant through photosynthesis. If a coyote eats the rabbit, some of the energy is transferred from the rabbit to the coyote. As shown in **Figure 1.2**, the clover, rabbit, and coyote ultimately get their energy from the sun. The clover is a **producer**, an organism that makes its own food. Producers are also called *autotrophs*, or self-feeders. The rabbit and the coyote are **consumers**, organisms that get their energy by eating other organisms. Consumers are also called *heterotrophs*, or other-feeders. Producers, such as plants, most algae, and some bacteria, absorb light energy directly from the sun. Consumers get energy indirectly from the sun by eating producers or other consumers.

**FIGURE 1.3**

**Deep-Ocean Ecosystem** These tube worms depend on bacteria that live inside them to survive. The bacteria (right) use energy from hydrogen sulfide to make their own food.



### An Exception: Deep-Ocean Ecosystems

In the depths of the ocean where there is no sunlight, you might not expect to find much life. But scientists have found large communities of worms, clams, crabs, mussels, and barnacles living near thermal vents in the ocean floor. These deep-ocean communities exist in total darkness, where photosynthesis cannot occur. So where do these organisms get their energy? One source of energy comes from organic matter that drifts down from above as organisms die. Another source comes from bacteria, such as those pictured in **Figure 1.3**, that live in some of these organisms. These bacteria use hydrogen sulfide to make their own food. Hydrogen sulfide is present in the hot water that escapes from the thermal vents. These sulfur-metabolizing bacteria produce carbohydrates using energy obtained from the chemical hydrogen sulfide in a process called *chemosynthesis*. The bacteria are eaten by other underwater organisms and thus support a thriving ecosystem.

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## What Eats What

Organisms can be classified by the source of their energy, as shown in **Figure 1.4**. Consumers that eat only plants are called *herbivores*. Rabbits are herbivores as are cows, sheep, deer, grasshoppers, and many other animals. Consumers, such as lions and hawks, that eat only other animals are called *carnivores*. You already know that humans are consumers, but what kind of consumers are we? Because humans can eat both plants and animals, we are called *omnivores*. Bears, pigs, and cockroaches are other examples of omnivores.

Consumers that get their food by breaking down organic matter from dead organisms are called **decomposers**. Some bacteria and fungi are decomposers. The decomposers allow the nutrients in the rotting material to return to the soil, water, and air.

### Connect to MATH

#### A Meal Fit for a Grizzly Bear

Grizzly bears are omnivores that can eat up to 15 percent of their body weight per day when eating salmon and up to 33 percent of their body weight when eating fruits and other vegetation. How many pounds of salmon can a 200 lb grizzly bear eat in one day? How many pounds of fruits and other vegetation can the same bear eat in one day?

**FIGURE 1.4**

#### WHAT EATS WHAT IN AN ECOSYSTEM

	Energy source	Examples
Producer	makes its own food using light energy (photosynthesis) or chemical sources (chemosynthesis)	grasses, ferns, cactuses, flowering plants, trees, algae, and some bacteria
Consumer	gets energy by eating producers or other consumers	mice, starfish, elephants, turtles, humans, and ants

#### TYPES OF CONSUMERS IN AN ECOSYSTEM

	Energy source	Examples
Herbivore	producers	cows, sheep, deer, and grasshoppers
Carnivore	other consumers	lions, hawks, snakes, spiders, sharks, and whales
Omnivore	both producers and consumers	bears, pigs, gorillas, rats, raccoons, cockroaches, some insects, and humans
Decomposer	breaks down organic matter from dead organisms	fungi and bacteria



**Consumers** Bears, such as this grizzly bear, are omnivores. Grizzly bears eat other consumers, such as salmon, but they also eat various plants.

## Cellular Respiration: Burning the Fuel

So far, you have learned how organisms get energy. But how do they use the energy they get? To understand the process, use yourself as an example. Suppose you have just eaten a large meal. The food you ate contains a lot of energy. Your body gets the energy out of the food by using the oxygen you breathe to break down the food. By breaking down the food, your body obtains the energy stored in the food.

The process of breaking down carbohydrates to yield energy is called **cellular respiration**, which occurs inside the cells of organisms. This process is different from breathing, another form of *respiration*. During cellular respiration, cells absorb oxygen and use it to release energy from food. As you can see in **Figure 1.5**, the chemical equation for cellular respiration is essentially the reverse of the equation for photosynthesis. During cellular respiration, sugar molecules are broken down in the presence of oxygen, yielding energy. Water and carbon dioxide are waste products.

**FIGURE 1.5**

**Cellular Respiration** Through cellular respiration, cells use sugar and oxygen to produce carbon dioxide, water, and energy.



### CASESTUDY

## DDT in an Aquatic Food Chain

In the 1950s and 1960s, something strange was happening in the estuaries near Long Island Sound, near New York and Connecticut. Birds of prey, such as ospreys and eagles, that fed on fish in the estuaries had high concentrations of the pesticide DDT in their bodies. But when the water in the estuaries was tested, it had low concentrations of DDT.

What accounted for the high levels of DDT in the birds? Poisons that dissolve in fat, such as DDT, can become more concentrated as they move up a food chain in a process called *biological magnification*. When the pesticide enters the water, algae and bacteria take in the poison. When fish eat the algae and bacteria, the poison dissolves into the fat of the fish rather than diffusing back into the water. Most of the poison remains in an animal's body once it is eaten. Each time a bird feeds on a fish, the bird accumulates more DDT in its fatty tissues. In some estuaries on Long Island Sound, DDT concentrations in fatty tissues of organisms were magnified almost 10 million times from the bottom to the top of the food chain.

Large concentrations of DDT may kill an organism, weaken its immune system, cause deformities, or impair its ability to reproduce.



A high concentration of DDT decreases the thickness and the strength of eggshells of many birds of prey.

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You use a part of the energy you obtain through cellular respiration to carry out your daily activities. Every time you walk, breathe, sleep, think, or play a sport, you use energy. The energy you obtain is also used to make more body tissues and to fight diseases so that you grow and stay healthy. Excess energy you obtain is stored as fat or sugar. All living things use cellular respiration to get the energy they need from food molecules. Even organisms that make their own food through photosynthesis use cellular respiration to obtain energy from the carbohydrates they produce.

## Energy Transfer

Each time one organism eats another organism, a transfer of energy occurs. In order to understand and manage ecosystems, environmental scientists must be able to trace the flow of energy through ecosystems. They also need to know how much energy flows to different parts of the ecosystem. By knowing how energy flows within an ecosystem and how much energy different species use, scientists can find out how organisms depend on one another to survive.

### Connect to CHEMISTRY

#### Chemical Equations

A chemical equation is a shorthand description of a chemical reaction using chemical formulas and symbols. The starting materials in a reaction are called *reactants*, and the substances formed from a reaction are called *products*. The number of atoms of each element in the reactants equals the number of atoms of those elements in the products to make a balanced equation.



Poisons such as DDT have the greatest effect on organisms at the top of food chains. For example, the osprey shown here would have a greater concentration of DDT in its body than the perch it's about to eat.

DDT can also weaken the shells of bird eggs. When eggs break too soon, bird embryos die. Therefore, the effects of these chemicals cause a huge drop in the population of carnivorous bird species.

The U.S. government recognized DDT as an environmental contaminant and in 1972 banned its sale except in emergencies. The aquatic food chains immediately started to recover, and the populations of ospreys and eagles started to grow.

Food chains are still not free of DDT. DDT is still legal in some countries where, for example, it is sometimes used

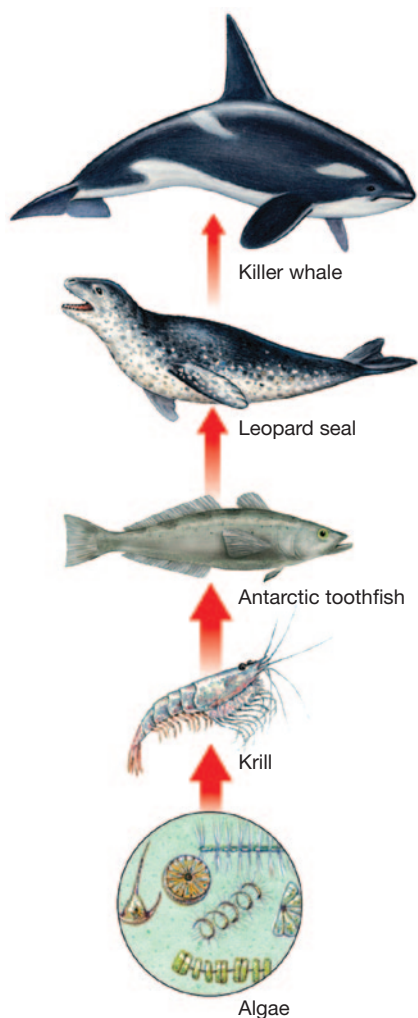
in large quantities to eliminate mosquitoes that carry the disease malaria.

#### Critical Thinking

- Analyzing Processes** DDT does not dissolve readily in water. If it did, how would the accumulation of the pesticide in organisms be affected?
- Evaluate** Even though DDT is harmful to the environment, why is it still used in some countries?

**FIGURE 1.6**

**Food Chain** Energy is transferred from one organism to another in a food chain. Algae are the producers in this ocean food chain.



## Food Chains and Food Webs

A **food chain** is the path in which energy is transferred from one organism to the next as each organism eats another organism. **Figure 1.6** shows a typical food chain in an ocean ecosystem. Algae are eaten by krill, which are eaten by fish, such as the Antarctic toothfish. These fish, in turn, are eaten by leopard seals, which are eaten by killer whales.

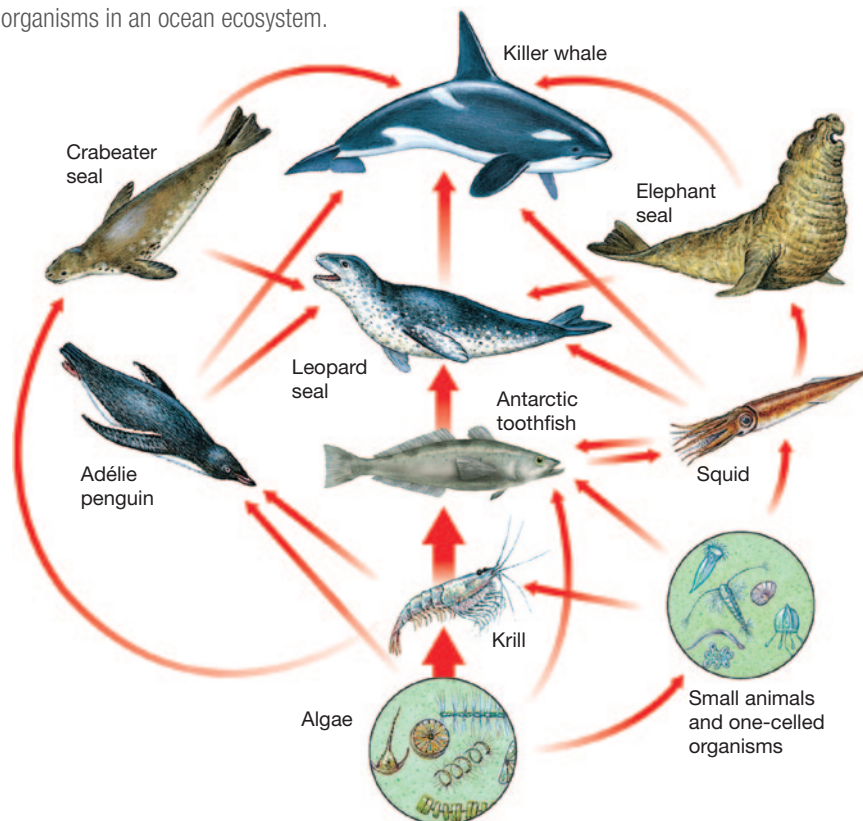
In natural ecosystems, energy does not flow in simple chains. Most organisms eat more than one kind of food, and many species are eaten by more than one predator. A food web, such as the one shown in **Figure 1.7**, is a better depiction of energy flow in ecosystems. A **food web** includes more organisms and shows the feeding relationships between organisms that are possible in an ecosystem.

## Trophic Levels

Each step through which energy is transferred in a food chain is known as a **trophic level**. In **Figure 1.6**, the algae are in the bottom trophic level (trophic level 1), the krill are in the next level (trophic level 2), and so on. Each time energy is transferred from one organism to another, less energy is available to organisms at the next trophic level. Some of the energy is lost as heat. Organisms use much of the remaining energy to carry out life functions, such as cellular respiration and moving.

**FIGURE 1.7**

**Food Web** This food web shows how the largest organisms depend on the smallest organisms in an ocean ecosystem.



Because organisms require energy for all of their life functions, only about 10 percent of the energy from one trophic level is stored in the bodies of organisms at the next level. This 10 percent that is stored is all that is available to the next trophic level when one organism consumes another organism.

## Energy Pyramids

One way to visualize the loss of energy from one trophic level to the next is to draw an energy pyramid like the one shown in **Figure 1.8**. Each level in the energy pyramid represents one trophic level. Producers form the base of the pyramid, the lowest trophic level, which contains the most energy. Herbivores make up the second level. Carnivores that feed on herbivores form the next level, and carnivores that feed on other carnivores make up the top level. The higher the trophic level, the less stored energy there is to be passed on.

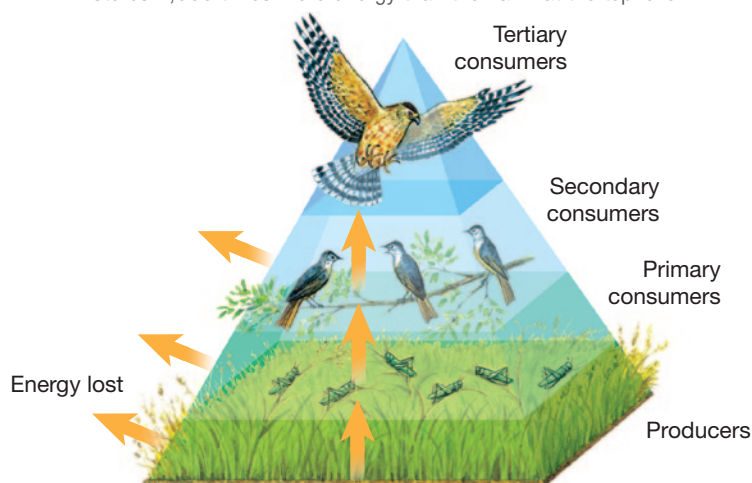
## How Energy Loss Affects an Ecosystem

The decreased amount of energy at each trophic level affects the organization of an ecosystem. First, because so much energy is lost at each level, there are fewer organisms at the higher trophic levels. For example, zebras and other herbivores vastly outnumber lions and other predators on the African savanna. In this example, there simply are not enough herbivores to support more carnivores.

Second, the loss of energy between trophic levels limits the number of trophic levels in an ecosystem. Ecosystems rarely have more than four or five trophic levels because the ecosystem does not have enough energy left to support higher levels. For example, a lion typically needs up to 250 km<sup>2</sup> of land to hunt for food. Killer whales may have to move across hundreds or thousands of kilometers during their foraging. The organisms that feed on organisms at the top trophic level are usually small, such as parasitic worms and fleas that require a very small amount of energy.

**FIGURE 1.8**

**Energy Pyramid** This energy pyramid shows how energy is lost from one trophic level to the next. The grass at the bottom level stores 1,000 times more energy than the hawk at the top level.



## Section 1 Formative Assessment

### Reviewing Main Ideas

1. **Describe** how energy is transferred from one organism to another.
2. **Describe** the role of producers in an ecosystem.
3. **Explain** the difference between an herbivore and an omnivore.
4. **Compare** energy transfer in a food chain to energy transfer in a food web.

### Critical Thinking

5. **Interpreting Graphics** Explain the feeding relationships of the crabeater seal in Figure 1.7.
6. **Inferring Relationships** Could more people be supported by 20 acres of land if they ate only plants instead of both plants and animals? Explain your answer.